



# Micro Grid Research & Business Development in Korea

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**KEPCO Research Institute  
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# BACKGROUND & NECESSITY

- Environment & Energy Problems  
→ Renewable Energy
- Economical & Technical Development  
→ Promoted Diffusion

- Competitive Power Market
- Global Environment Problems
- NIMBY Syndrome
- Stability & Security of Power : Black-out

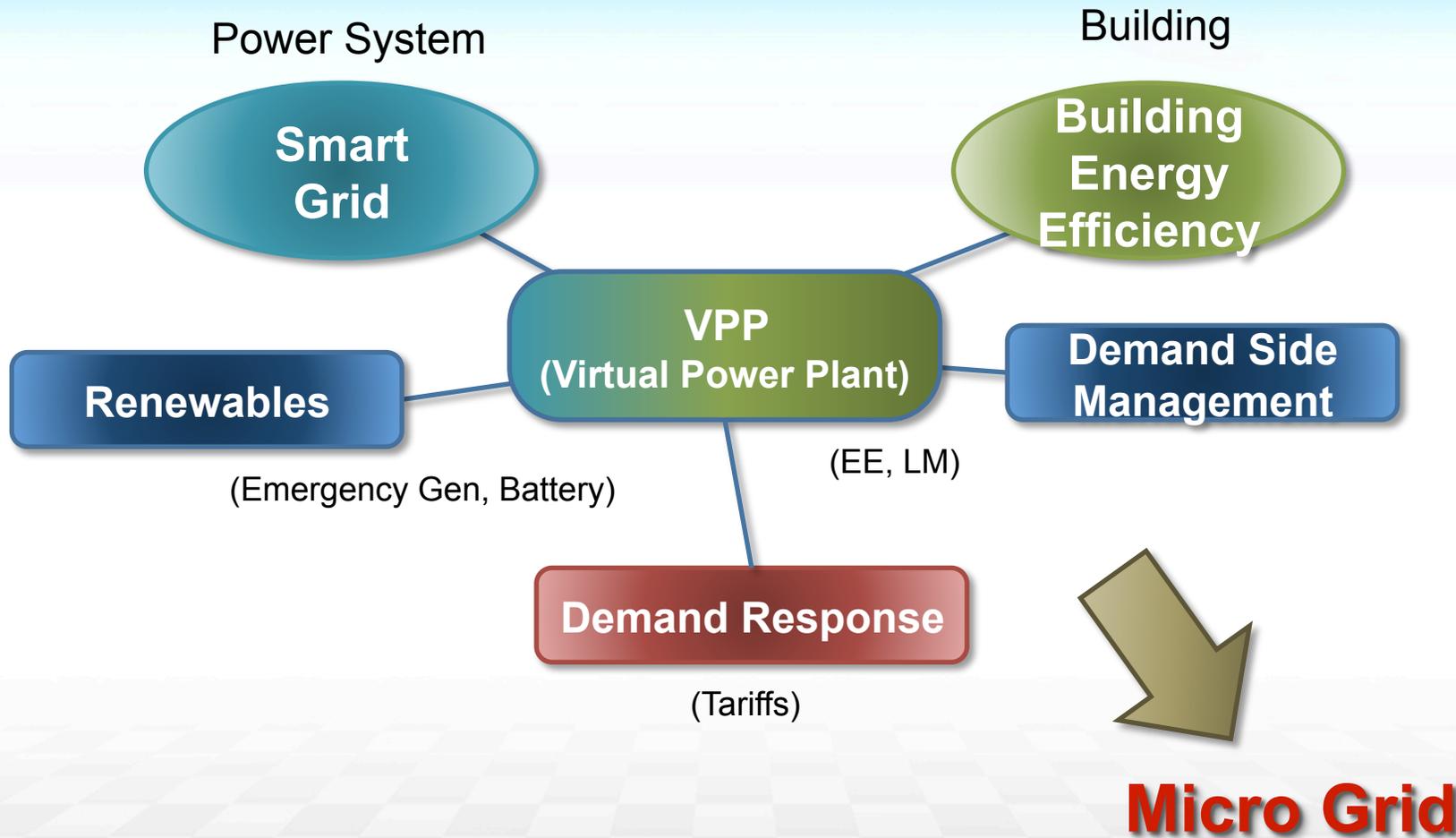
**Economic & Efficient  
Operation of DER**

**Alternative for  
Concentrated Power System**

**Micro Grid**

- ✓ Extension of DER Introduction → Harmonious Coexistence with Conventional Grid
- ✓ Efficient & Stable Use of DER → Enhancement of Power Quality & Reliability

# RECOGNITION OF MICRO GRID



# PREVIOUS WORK

## Overview

**Goal** : To demonstrate Microgrid & its optimal operation tech.

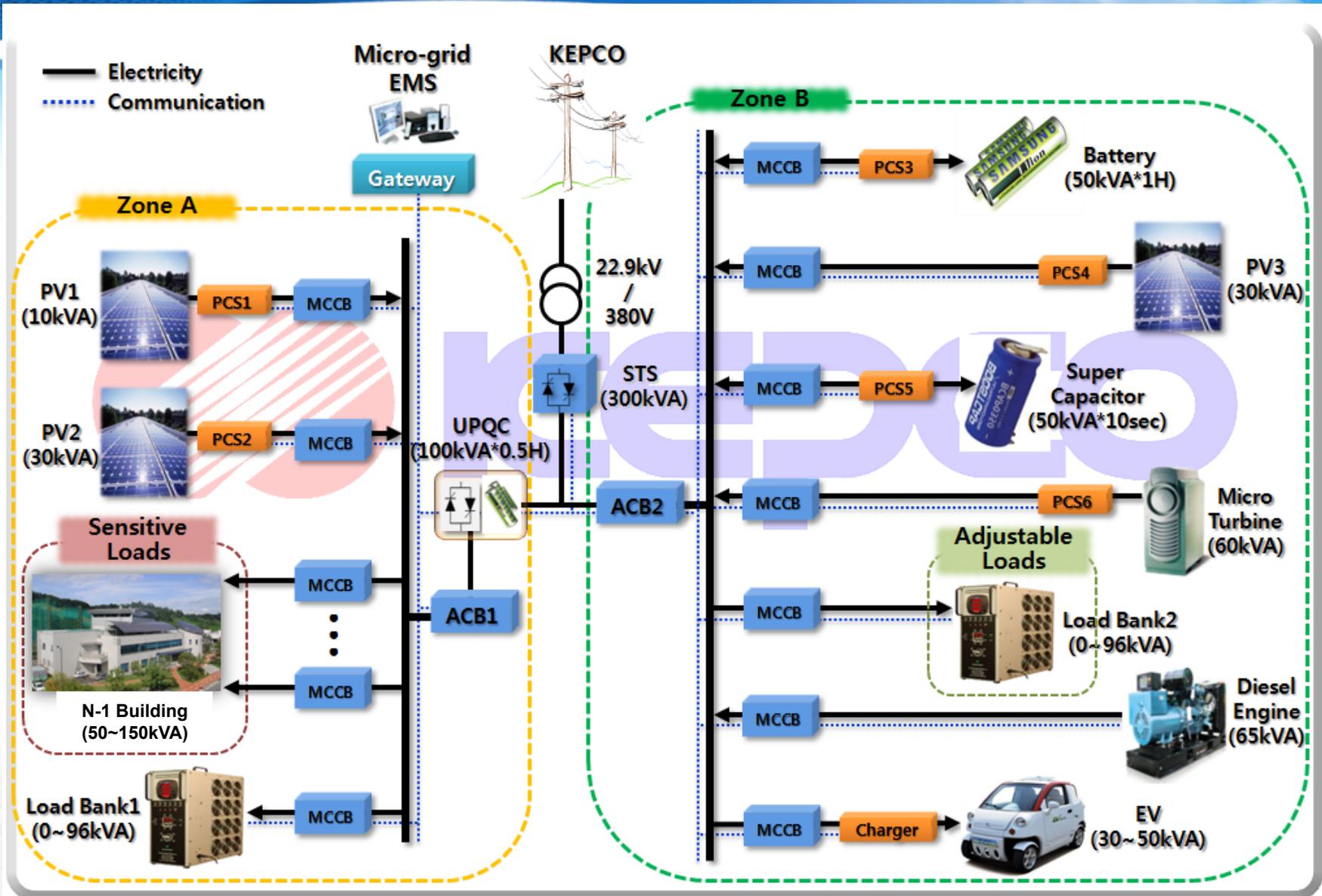
**Period/Budget** : 2010. 2 ~ 2013.1 (36 months) / \$ 4.2 million

**Participants** : KEPCO, LS Industrial, Sanion, Inha University

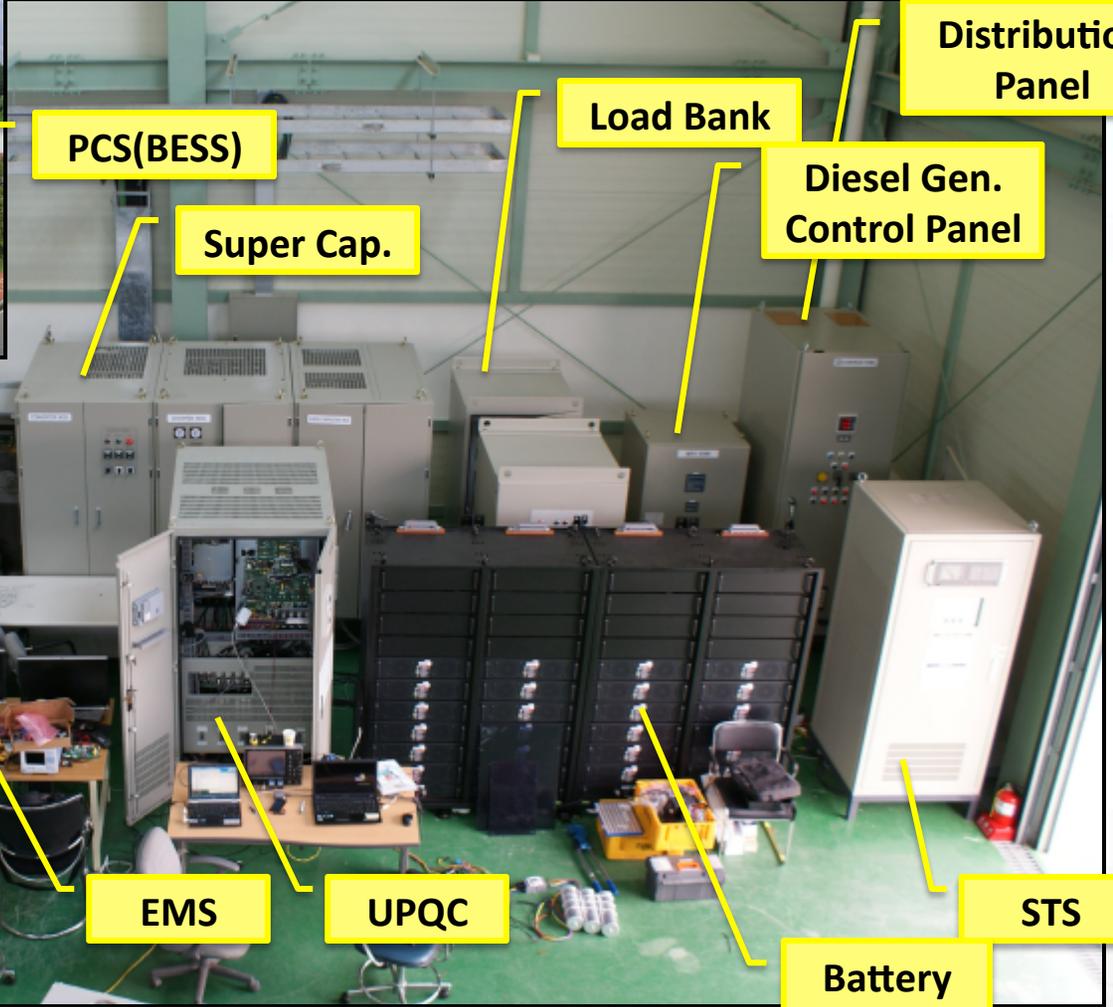
## Goals and Schedule

- **Development of the core devices for Microgrid(MG)**
  - Development the Microgrid EMS
  - Network Gateway, PCS for PV/BESS
  - UPQC for MG power quality, STS(Static Transfer Switch)
- **Build & Actual Load Test in KEPCO 200kW MG site**
- **Development of the engineering technology for MG**
- **Develop the optimal operation strategies of MG**
- **Schedule**
  - ~2012. 1 : Build of 200kW Microgrid Site at KEPCO RI
  - ~2013. 1 : Actual Load Test & Optimal Operation

# SYSTEM ARCHITECTURE



# TEST SITE



PCS(BESS)

Super Cap.

Load Bank

Distribution Panel

Diesel Gen. Control Panel

Controller (PQM, Weather, Load Bank)

Battery (PCS)

EMS

UPQC

Battery (UPQC)

STS

[Picture of the test site at Daejeon, Korea]

# CORE DEVICES AND ITS FUNCTIONS

Core Device	Main Function
EMS	<ul style="list-style-type: none"> <li>• Load/Generation(PV, WT) forecasting, AGC/ED</li> <li>• Device Management : BESS, Load, Distributed Generation</li> <li>• Power Exchange &amp; Metering, Interconnection with DMS/DAS</li> </ul>
STS/IED	<ul style="list-style-type: none"> <li>• MG Protection from upper power system</li> <li>• Fast open at upper system fault and resynchronization</li> <li>• Power quality and power flow monitoring at PCC</li> </ul>
PCS(BESS)	<ul style="list-style-type: none"> <li>• Power converting of DC power of BESS into AC power</li> <li>• Droop operation : Active power &amp; Reactive power</li> <li>• P &amp; Q control by EMS command</li> </ul>
PCS(PV)	<ul style="list-style-type: none"> <li>• Power converting of DC power of PV into AC power</li> <li>• Power limit &amp; Power factor control by EMS command</li> </ul>
Gateway	<ul style="list-style-type: none"> <li>• Protocol conversion : Serial/Field Bus/Ethernet -&gt; IEC61850</li> </ul>
UPQC	<ul style="list-style-type: none"> <li>• Power quality Compensation : Sag, Swell, Harmonics, Flicker...</li> <li>• Uninterruptable power supply for sensitive loads</li> </ul>
Super Cap.	<ul style="list-style-type: none"> <li>• Improvement of MG's transient stability due to fast response</li> </ul>

# EMS – FUNCTION

## MG Control

### EMS Function

- Export & Import Power Control at PCC (Completed)
- Supervisory Control of BESS (Completed)
- Forecasting : Load (Power & Heat) & Renewable Energy Generation
- Generation Scheduling : Unit Commitment (including CHP)
- Economic Dispatch



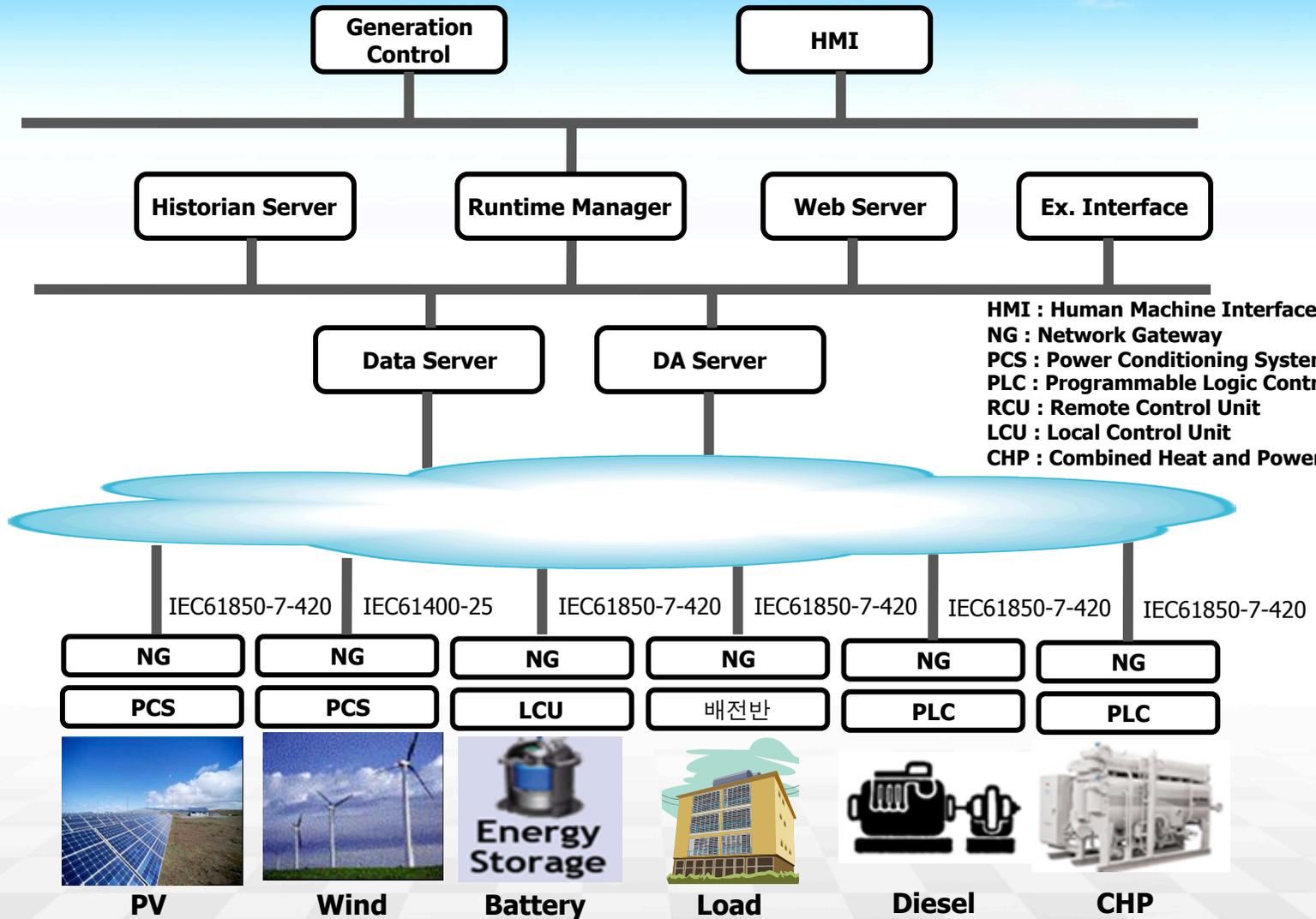
### Generation Schedule & Dispatch

- Make the balance between demand & supply
- Optimize the objective related to Microgrid
- For the generation schedule & dispatch : Forecast (Load & Renew. Gen.), UC and ED

### Supervisory Control

- Tie-line control (power & voltage control at PCC)
- Power system fault detection and disconnection
- Reconnection to power system
- Secondary regulation regarding energy storage

# EMS - STRUCTURE



# CONTENTS OF FIELD TEST

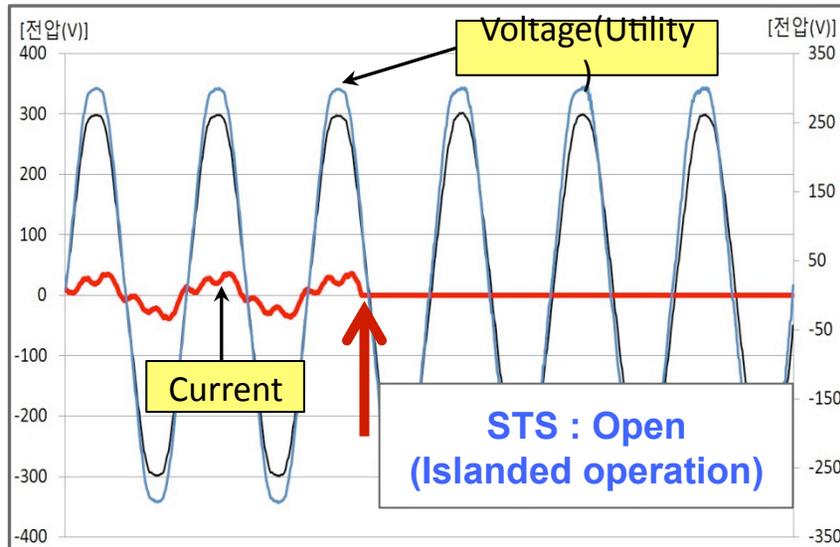
Mode	Contents of Test	Purpose of Test
Interconnected	<ul style="list-style-type: none"> <li>-Max operation capability</li> <li>-Power flow control at PCC</li> <li>-Thermal load following</li> </ul>	<ul style="list-style-type: none"> <li>-Verification of installed generator</li> <li>-Peak shaving, Power sales..</li> <li>-Optimal thermal supply</li> </ul>
Standalone	<ul style="list-style-type: none"> <li>-Voltage &amp; Frequency control</li> <li>-Keep supply and demand in balance</li> </ul>	<ul style="list-style-type: none"> <li>-Island operation at interruption</li> <li>-Power supply for island, isolated area</li> </ul>
Transition	<ul style="list-style-type: none"> <li>-Transient stability by power flow quantity at PCC</li> </ul>	<ul style="list-style-type: none"> <li>-Cooperated control using BESS &amp; Super Capacitor</li> <li>-Stable transition at interruption</li> </ul>
Re-sync	<ul style="list-style-type: none"> <li>-Seamless re-sync by STS &amp; EMS</li> </ul>	<ul style="list-style-type: none"> <li>-Stable coexistence with Distribution System &amp; Utility</li> <li>-Improvement of power quality</li> </ul>

# TEST RESULTS

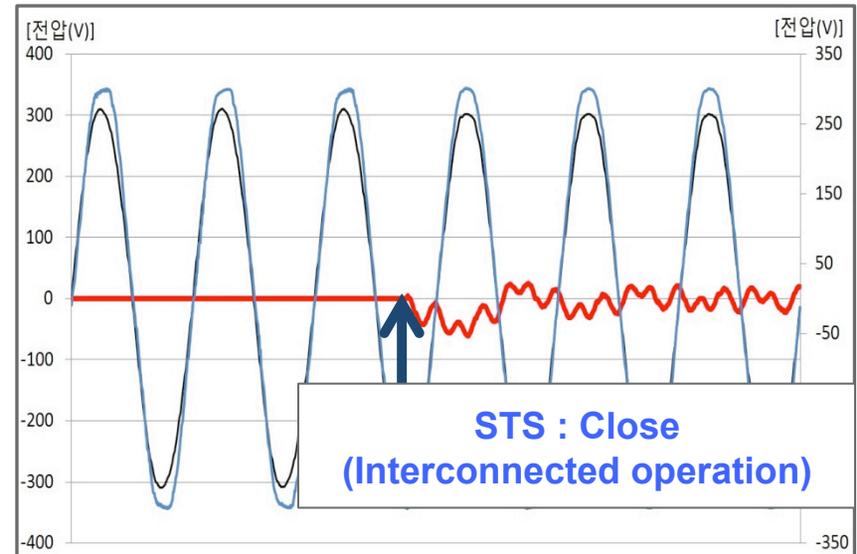
## ▶ Operation Mode Transfer

- Field test of seamless operation mode transfer

### ① Interconnected → Standalone



### ② Standalone → Interconnected

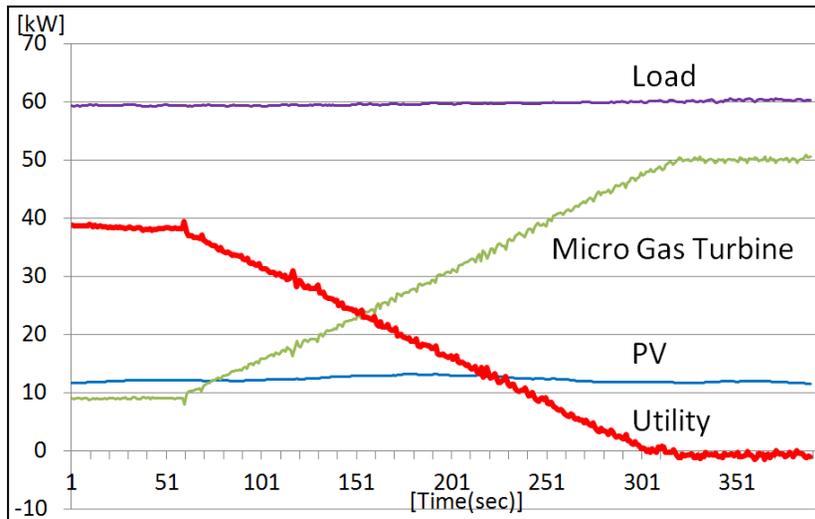


- Seamless operation mode transfer under 20% power flow
- Reliability of the delivery is raised(No momentary interruption)

# TEST RESULTS

## ▶ Feeder Flow Control▶

- Power Exchange
- Maximum Demand Control

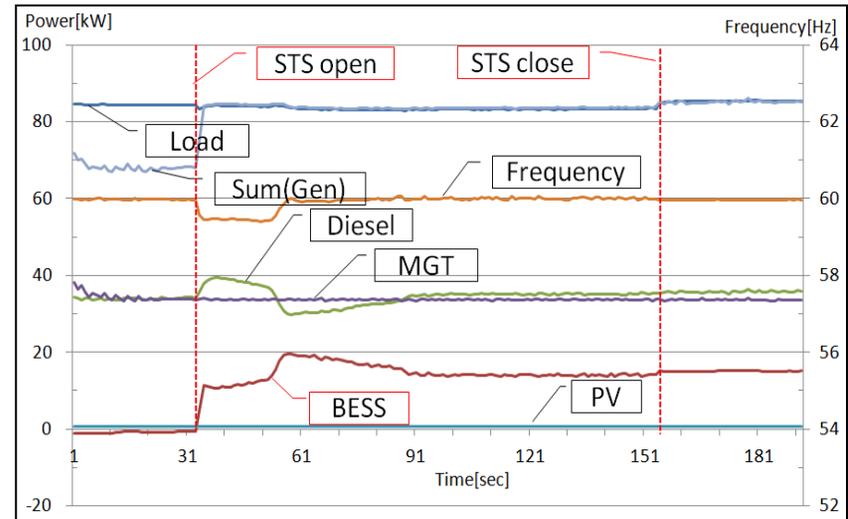


### Results

- Power flow at PCC can be controlled automatically by EMS.
- Peak and facility investment reduction

## ▶ Frequency Control▶

- Frequency control under islanded mode using BESS and diesel generator

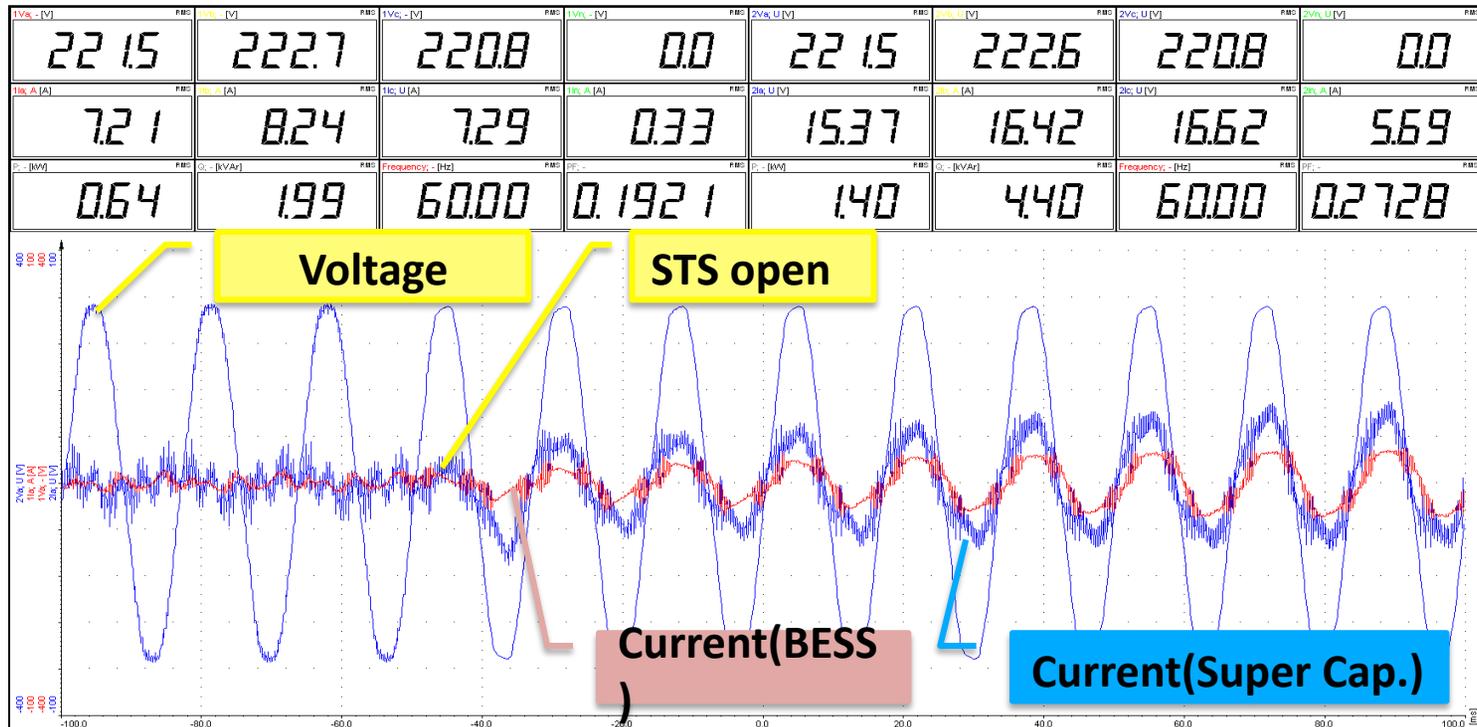


### Results

- Frequency can be controlled by BESS's droop function(Diesel : P/Q control mode)
- Continuous power supply at emergency

# TEST RESULTS

## ▶ Cooperative operation between BESS and Super Capacitor



- ◆ Cooperative operation using Droop function under mode transfer
  - Super cap. discharge the power due to its fast response.
  - BESS discharge the power using droop function.
  - MG's Stability would be raised and BESS's life time would be prolonged.

# ISLAND MG (Oct.12~Sept.15)

## Goal

Secure **MicroGrid Total Solution** for overseas business

## What to develop

### Develop engineering program

- optimal combination of DG and evaluation of economic feasibility
- system analysis and optimal location of DG

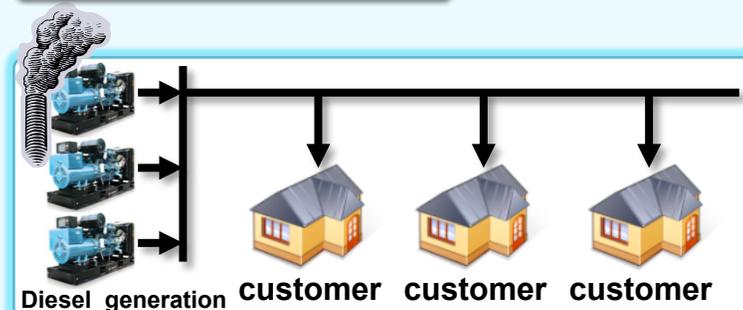
### Develop EMS and operating technology

- generation control, emergency control, load control, etc.
- operation manual, emergency operation manual

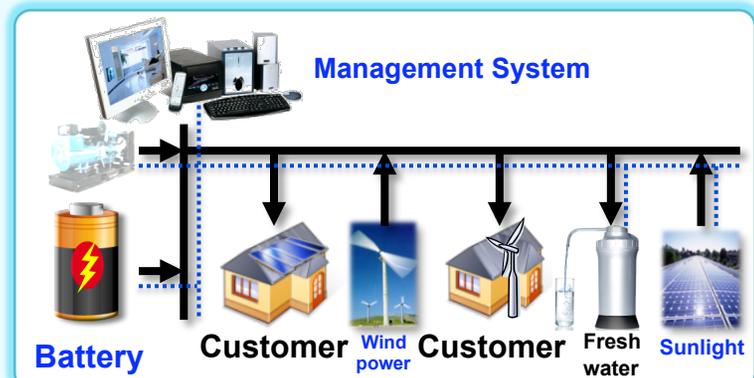
### Demonstrate and secure Track Record

- verify technology based on DG capacity combination
- Build infrastructure for commercialization through site optimization

## Concept diagram



[Before applying island MG technology]



[After applying island MG technology]

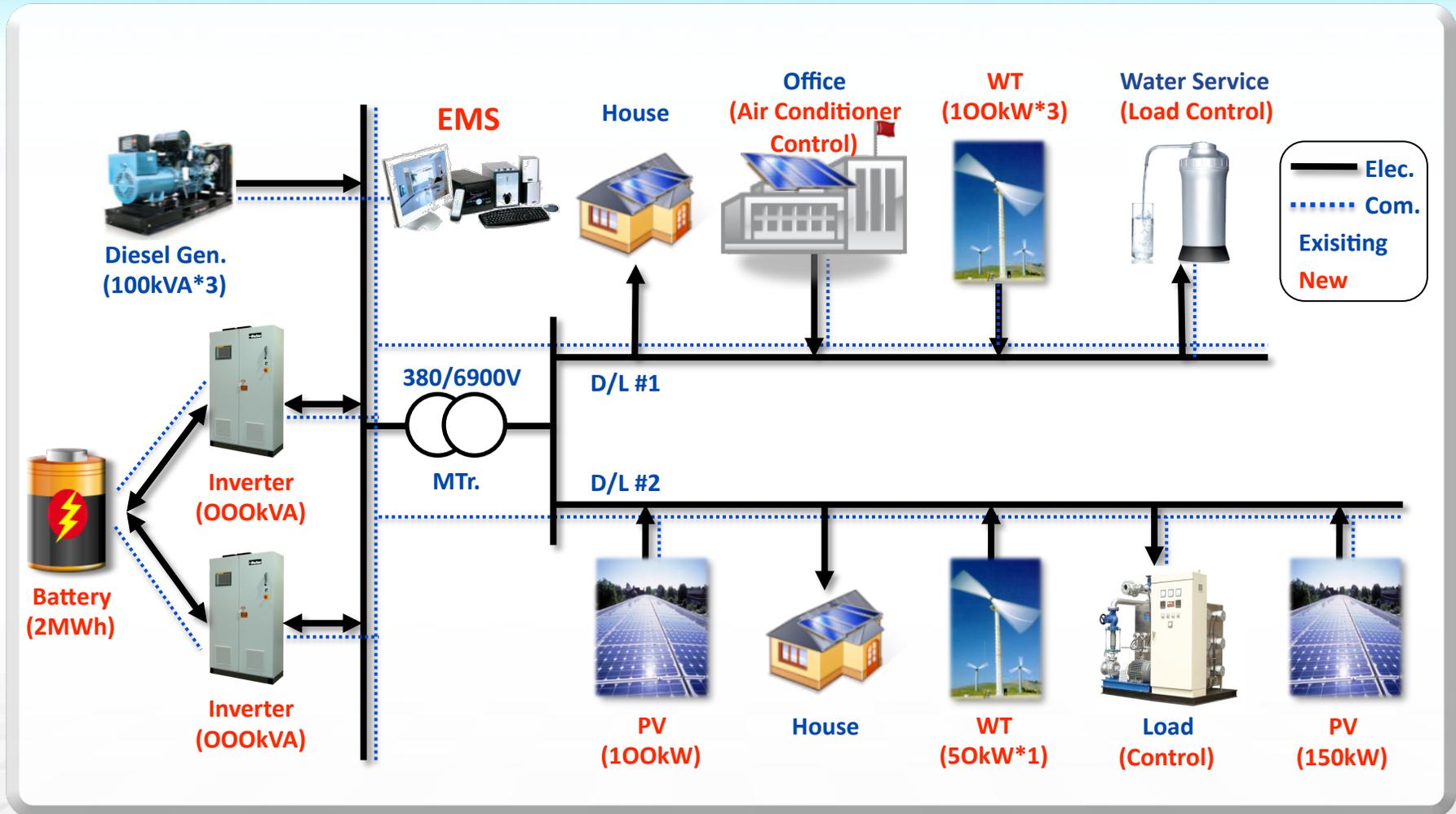
# ISLAND MG (Oct.12~Sept.15)

## MicroGrid concept design using 99% renewable energy

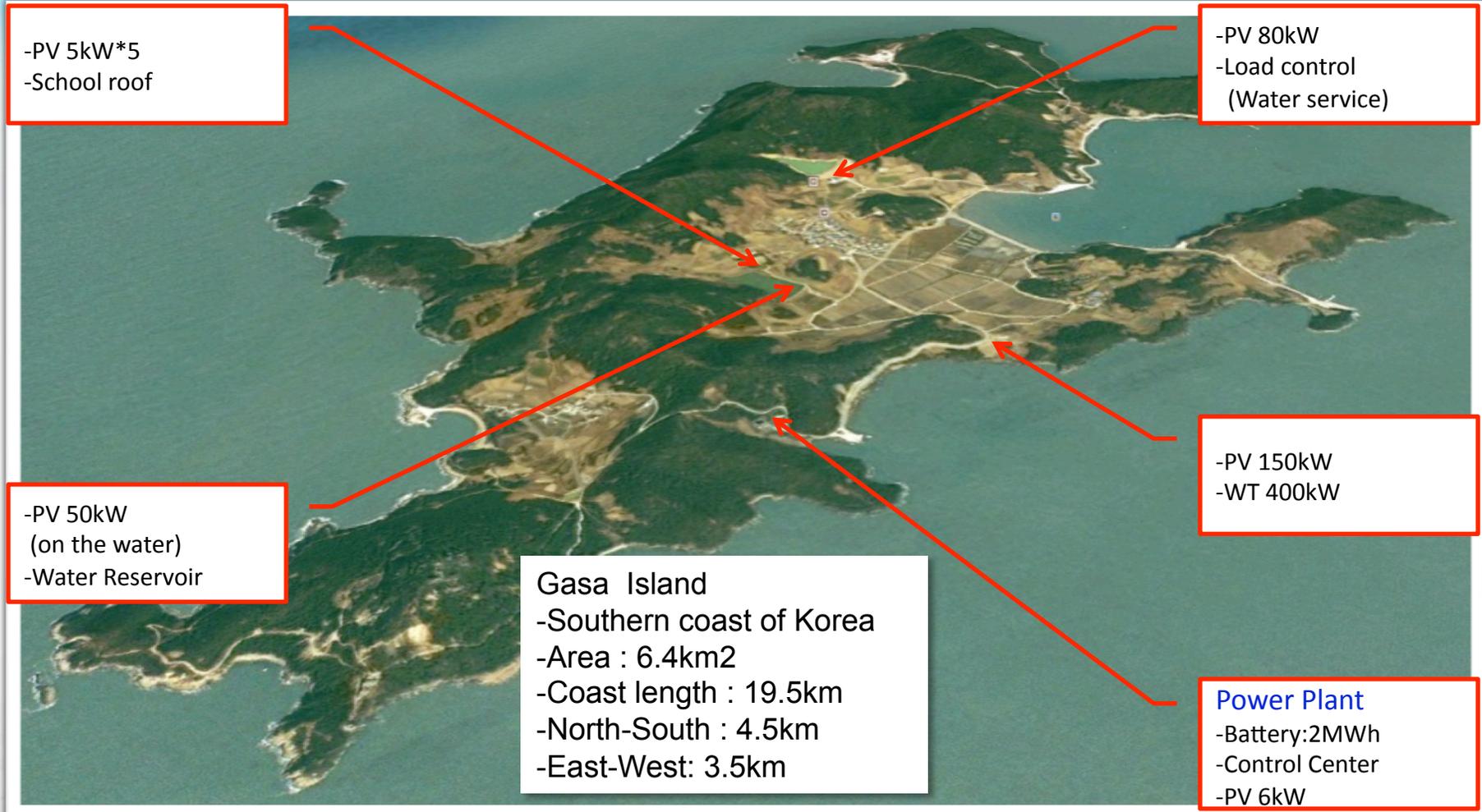
Classification	Contents	Note
Energy	99% renewable energy	Energy independent
No renewable	1 day	Battery size, Economical
Emergency	Diesel generator	WT/PV fault
Field test	Renewable mix test	Capacity divide
EMS	Automatic control	System efficiency
Plug&Play	No comm. for small PV	Economical
Site for WT/PV	Building roof, idle site	

# ISLAND MG (Oct.12~Sept.15)

## ● Schematic diagram for Gasa-island

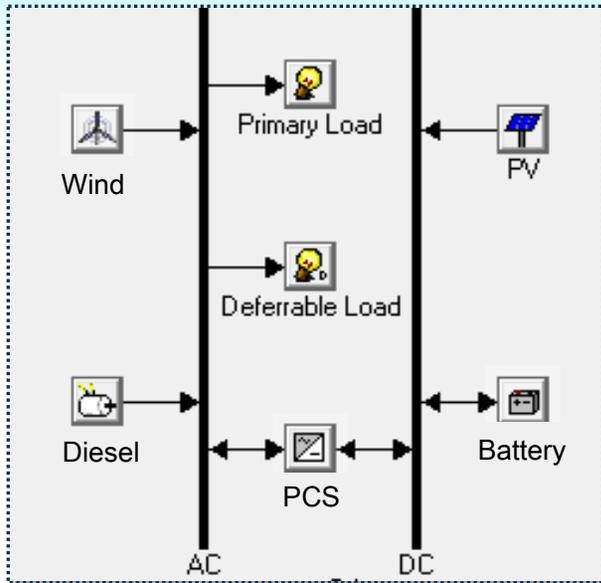


# RENEWABLE RESOURCE LOCATIONS



# SAMPLE SYSTEM

## A Sample System with PV, WT & ESS



### Resource

- PV : 200kW, Wind : 300kW, Diesel : 200kW
- ESS : 2MWh battery & 500kW PCS

### Load Status

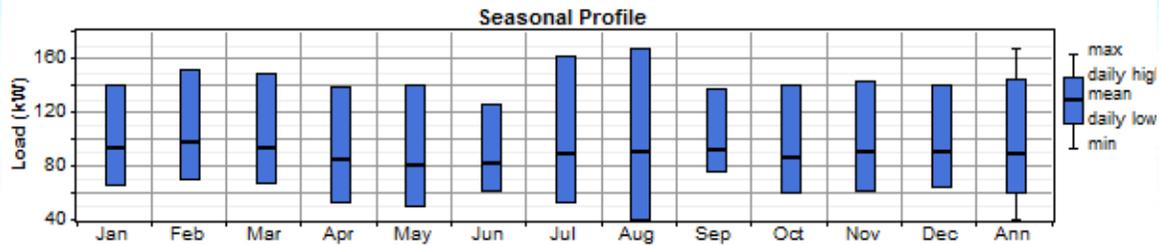
- Average Consumption(kWh/d) : 2,165
- Average Load(kW) : 90.2
- Peak Load(kW) : 167
- Deferrable Load(kWh/d) : 36

## Monthly Average Load Patterns of the Island G

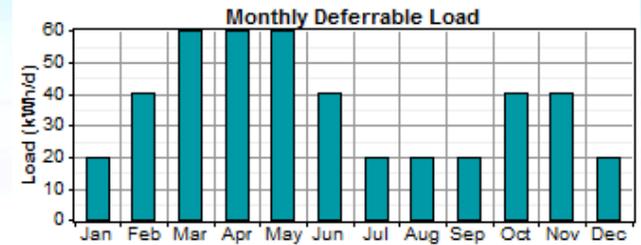
Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
00:00-01:00	82	85	82	72	67	72	73	72	83	75	77	80
01:00-02:00	76	79	76	65	60	68	65	60	80	69	71	74
02:00-03:00	74	78	75	63	59	67	63	56	80	67	70	72
03:00-04:00	77	80	77	66	62	69	67	62	81	70	72	75
04:00-05:00	66	70	67	53	50	62	53	40	76	60	62	64
05:00-06:00	91	93	90	83	76	78	84	90	87	83	86	89
06:00-07:00	92	94	90	83	77	78	85	90	87	83	86	89
07:00-08:00	83	86	82	73	68	73	74	73	84	75	78	81
08:00-09:00	104	107	103	98	91	88	102	113	96	95	101	101
09:00-10:00	107	110	106	101	95	91	106	117	99	99	105	104
10:00-11:00	89	91	88	80	74	76	81	85	86	81	84	86
11:00-12:00	75	78	75	63	59	67	64	57	80	68	70	72
12:00-13:00	73	76	73	61	57	66	61	53	79	66	68	70
13:00-14:00	80	83	80	70	65	71	71	68	82	73	75	78
14:00-15:00	78	81	78	67	62	69	68	63	81	71	73	76
15:00-16:00	76	79	76	65	60	68	65	60	80	69	71	74
16:00-17:00	84	87	84	75	69	74	76	76	84	76	79	82
17:00-18:00	127	135	132	124	123	112	140	148	122	124	128	126
18:00-19:00	140	151	148	138	140	126	161	167	137	140	143	140
19:00-20:00	133	143	140	131	131	119	150	157	129	132	135	133
20:00-21:00	136	146	143	133	134	121	154	160	132	135	138	135
21:00-22:00	113	117	114	107	102	97	116	126	106	106	111	110
22:00-23:00	101	102	99	94	86	84	96	108	92	91	98	98
23:00-00:00	101	103	99	94	87	85	97	109	93	92	98	98

# INPUT DATA

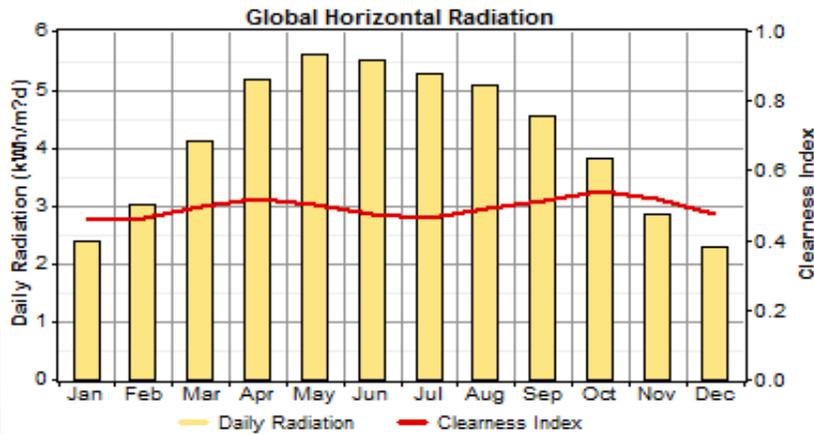
## Annual Load Profile Data for the Island G



## Annual Deferrable Load

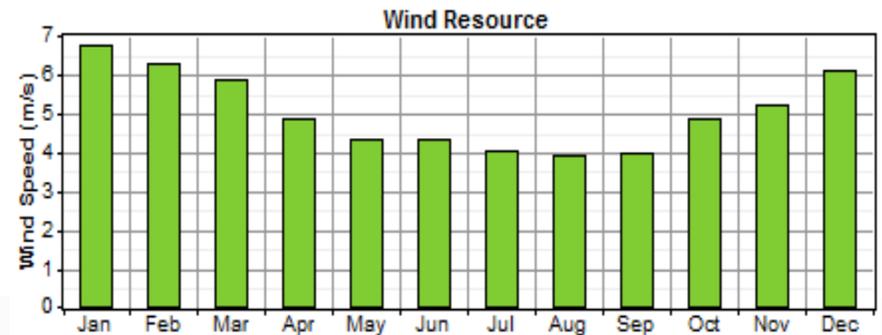


## Annual Radiation Data of the Island G



➤ Average Radiation : 4.136 kWh/m<sup>2</sup>/d

## Annual Wind Speed of the Island G

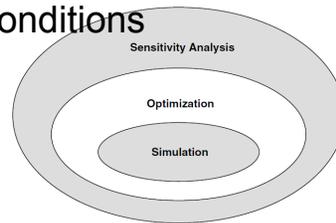


➤ Average Wind Speed : 5.05 m/s

# SIMULATION RESULTS (1)

## Using the Simulation tool HOMER

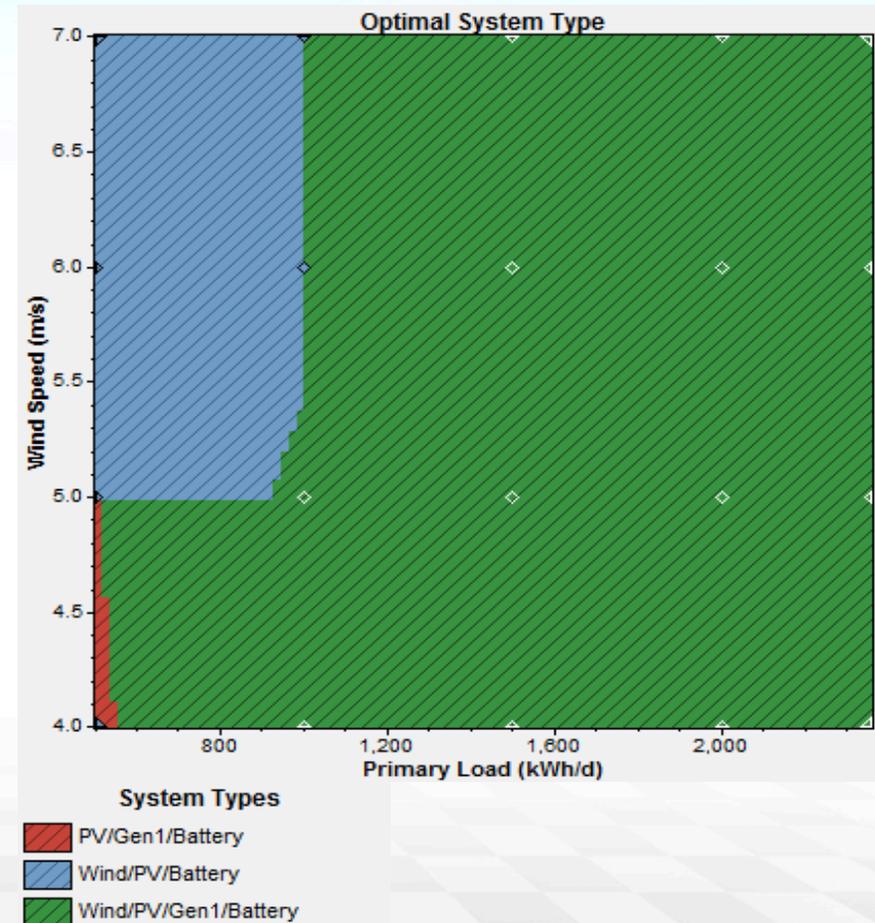
- Developer : NREL
- An Optimization Model to Design on/off-grid Systems Including Various Renewable Resources
- Explore
  - Cost-effectiveness
  - Component size
  - Sensitivity by various conditions



## Simulation Conditions

- **Resource Configuration**
  - PV : 50 / 100 / 150 / 200 kW
  - Wind : 100 / 200 / 300 kW
  - Diesel : 100 / 200 kW
  - PCS : 250 / 500 kW
- **Variation**
  - Wind Speed : 4~7 m/s
  - Load Level : 500~2500 kWh/d
  - Diesel Consumption : 100,000~200,000 L/year

## An Optimal Resource Configuration



# SIMULATION RESULTS (2)

● Diesel consumption limit 200,000 L/year, wind speed 7 m/s and primary load 2,356 kWh/d

#	Capacity (kW)				Total NPC (\$)	COE (\$/kWh)	Production(kWh)			Diesel Consumption (L/year)
	PV	WIND	DIESEL	PCS			PV	WIND	DIESEL	
1	200	300	100	250	3,206,736	0.323	268,803	1,004,844	100,738	31,828
2	0	300	200	250	4,440,458	0.443	0	1,004,844	229,871	72,649
3	200	300	200	250	7,850,700	0.784	268,803	1,004,844	421,548	133,239

● Diesel consumption limit 200,000 L/year, wind speed 4 m/s and primary load 2,356 kWh/d

#	Capacity (kW)				Total NPC (\$)	COE (\$/kWh)	Production(kWh)			Diesel Consumption (L/year)
	PV	WIND	DIESEL	PCS			PV	WIND	DIESEL	
1	200	300	200	250	7,621,607	0.761	268,803	255,967	420,706	132,960
2	200	0	200	250	8,763,505	0.882	268,803	0	632,738	199,952
3	0	300	200	250	9,263,818	0.937	0	255,967	632,664	199,938

● Diesel consumption limit 150,000 L/year, wind speed 7 m/s and primary load 1,500 kWh/d

#	Capacity (kW)				Total NPC (\$)	COE (\$/kWh)	Production(kWh)			Diesel Consumption (L/year)
	PV	WIND	DIESEL	PCS			PV	WIND	DIESEL	
1	150	200	100	250	2,132,469	0.332	201,602	669,897	39,389	12,448
2	0	300	100	250	2,174,243	0.338	0	1,004,844	67,712	21,397
3	0	300	100	0	4,205,354	0.654	0	1,004,844	248,233	78,448

# SIMULATION RESULTS (3)

● Diesel consumption limit 150,000 L/year, wind speed 4 m/s and primary load 1,500 kWh/d

#	Capacity (kW)				Total NPC (\$)	COE (\$/kWh)	Production(kWh)			Diesel Consumption (L/year)
	PV	WIND	DIESEL	PCS			PV	WIND	DIESEL	
1	200	300	100	250	3,862,416	0.601	268,803	255,967	144,085	45,532
2	200	0	100	250	4,664,920	0.726	268,803	0	330,710	104,499
3	0	300	100	250	5,181,091	0.807	0	255,967	345,270	109,100

● Diesel consumption limit 100,000 L/year, wind speed 7 m/s and primary load 500 kWh/d

#	Capacity (kW)				Total NPC (\$)	COE (\$/kWh)	Production(kWh)			Diesel Consumption (L/year)
	PV	WIND	DIESEL	PCS			PV	WIND	DIESEL	
1	50	100	0	250	672,329	0.305	67,201	334,949	0	0
2	0	100	100	250	896,196	0.399	0	334,949	10,676	3,375
3	0	200	0	250	897,329	0.4	0	669,897	0	0

● Diesel consumption limit 100,000 L/year, wind speed 4 m/s and primary load 500 kWh/d

#	Capacity (kW)				Total NPC (\$)	COE (\$/kWh)	Production(kWh)			Diesel Consumption (L/year)
	PV	WIND	DIESEL	PCS			PV	WIND	DIESEL	
1	150	300	0	250	1,137,329	0.507	201,602	85,322	0	0
2	200	0	100	250	1,276,105	0.568	268,803	0	6,186	1,956
3	150	300	100	250	1,360,790	0.606	201,602	85,322	570	180

# CONCLUSIONS (1)

## Research Status

- Global : wrap-up demonstration, stepping into **commercialization**
- Korea : **demonstration test in process** as national strategic project

## Importance of technology

- RES+DG → **MicroGrid** is a basic tech. of the distributed power system
- **Part of future power energy system** such as Smart Grid/Intelligrid

## Commercialization prospect

- Mid-, long-term Paradigm Shift: **converted into distributed power system**
- Developed countries : grid-connected, developing countries : independent
- **KEPCO is implementing demonstration and securing tract records.**

## CONCLUSIONS (2)

### ❖ Economic & Physical Evaluation of Standalone MG

- ✓ Configuration: PV 200kW, Wind 300kW, Diesel 200kW
- ✓ Using HOMER which is a powerful simulation tool for MG
- ✓ Applying the diesel consumption limit and comparing results
- ✓ As a result, diesel could be eliminated in lower electricity demand levels by means of adopting PV, Wind & ESS.

### ❖ Future Studies

- ✓ Feasibility Researches to Select Optimal Sites for MG Diffusion
- ✓ Policy Researches to Promote Diffusion of on/off-grid MG
- ✓ Development of MG Engineering and Business Models to Overseas Expansion

# TeamWork in MicroGrid Business

- Development of Economic and Exportable Island Type Microgrid

- Engineering
- Construction and Operation
- Development of Biz. Model

**KEPCO**

- Monitoring and Control
- Improvement of Efficiency
- Cost-down

**Realization of Eco-Island  
through Microgrid**

**Maker  
(EMS, PV,  
WT, PCS...)**

- Research of Theory
- Preceding Research

**University**

# Light the World



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